Laboratory Environment Safety and Health Committee
Cryogenic Safety Subcommittee

MINUTES OF MEETING 03-08

October 1, 2003

FINAL

Committee Members Present	**Committee Members Absent**
W. Glenn	M. Iarocci
E. Lessard (Chairperson)	S. Kane
P. Mortazavi	P. Kroon
M. Rehak	
R. Travis* (Secretary)	
K. C. Wu	

(* for T. Monahan)

Visitors

W. De Jong	E. Quimby
A. Etkin	A. Warkentien
R. Karol	A. Sidi-Yekhlef
A. Nicoletti	

Agenda:

1. Review of the New RHIC LN2 Tanks at Building 1005H

Minutes of Meeting: Appended on pages 2 through 3.

ESH COMMITTEE MINUTES APPROVED:

(Original Signed By:)
E. Lessard
LESHC Chairperson

DM2120.

Chairperson E. Lessard called the eighth meeting in 2003 of the Laboratory Environmental Safety and Health Committee (LESHC) to order on October 1, 2003 at 3:09 p.m.

1. **Review of the New RHIC LN2 Tanks at Building 1005H:** A. Nicoletti and E. Quimby presented the installation of the new RHIC LN2 tanks at Building 1005H. (These Minutes and the related material are posted at: http://www.rhichome.bnl.gov/AGS/Accel/SND/laboratory_environemnt,_safety_and_health_committee.htm.

   1.1. Mr. Nicoletti, Mr. Quimby and other attendees made the following points during the course of the presentation and in response to specific Committee questions:

   1.1.1. The focus of this meeting is cryogenic safety. C-AD will convene an ASSRC meeting to address any conventional safety issues.

   1.1.2. The installation replaces a low pressure (~ 40 psig) LN2 storage tank and associated nitrogen gas compressor. The compressor will be retained as a backup.

   1.1.3. The new system will be operated at a nominal pressure of 100 psig (133 psig max.). This will eliminate the need for the compressor to increase gas pressure for the "air" operated valves.

   1.1.4. The major components of the new configuration are two 6,000 gallon vacuum jacketed storage tanks and associated piping, valves and relief valves. These components were purchased in 1987 and were in use at the HFBR until the reactor was shutdown.

   1.1.5. Although the tanks have a maximum working pressure of 250 psig, the system was originally operated at a much lower pressure. The tank relief valve setpoints were changed to 50 psig at the HFBR

   1.1.6. The installation at Building 1005H required additional piping, valves and relief valves to connect the tanks with the existing nitrogen supply system (e.g., the purifier and vaporizers).

   1.1.7. All relief valves (existing and new) have been set for the new operating pressure.

   1.1.8. The tank relief valves (N2521R, N2557R) have been refurbished, reset to 150 psig and tested. These valves are assumed to be the original vendor supplied components. This should be confirmed - **Complete**[1].

   1.1.9. Each tank is also protected by a 157 psig rupture disk.

   1.1.10. The Bldg 1005H ODH classification of ODH zero is based on the former system configuration. This calculation should be updated with the higher system pressure of the new system.

   1.1.11. The three RVs on the transfer line discharge horizontally and are a potential personnel hazard.

   1.1.12. The existing relief valves (N2542R, N2544R) located upstream of the vaporizers were sized based on the original, low pressure configuration. The adequacy of these valves (i.e., sufficient relief capacity) must be confirmed for the new higher operating pressure.

[1] This action was completed prior to the issuance of these minutes.

1.1.13. Since the Committee is now acquainted with this system, the future hookup to the oil processing skid can be reviewed electronically, when it becomes available.

1.2. The following motion was crafted by the Committee:

1.2.1. Motion No. 1 – The cryogenic aspects of the new LN2 system[2] at Building 1005H are approved subject to the following conditions:

1.2.1.1. Revise the ODH calculation for Building 1005H to account for the higher flow rate of the new LN2 system configuration – **Complete**[1].

1.2.1.2. Confirm that the LN2 tank relief valves (currently labeled N2521R, N2557R) are the original manufacturer supplied valves – **Complete**[1].

1.2.1.3. Install discharge piping on the transfer line relief valves to redirect the discharge of cryogens away from personnel **- Complete**[1].

1.2.1.4. Confirm that the existing relief valves (N2542R, N2544R) located upstream of the vaporizers have sufficient relief capacity for the new (higher) operating pressure - **Complete**[1].

2. There was some discussion amongst the Committee members concerning the ASME code requirements for relief valve setpoint bench testing. It was acknowledged that this was a generic concern. A Committee member agreed to research the Code requirements, so that guidance can be provided to the Laboratory.

3. The Meeting was adjourned at 5:10 p.m.

4. Addendum to the Minutes

4.1. The purpose of this addendum is to document the salient points of the discussions and emails among Committee members and C-AD personnel that occurred after the 10/1/03 meeting.

4.1.1. C-AD will use the OPMs that were developed by the Reactor Division for the LN2 tank filling and initial operations.

4.1.2. Each tank will be filled initially with a limited volume of LN2 (approximately 1,000 gallons per tank).

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[2] The scope of the Committee review was limited to cryogenic safety. It is our understanding that the C-AD ASSRC will be convened to review the system and identify any conventional safety issues.

(Original Signed by E. Lessard)

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Managed by Brookhaven Science Associates
for the U.S. Department of Energy

Date: *October 7, 2003*

To: *J. Tarpinian, Assistant Laboratory Director for ESH&Q*

From: *E. Lessard, Chair, BNL Environment, Safety and Health Committee*

Subject: *LESHC 03-08, Recommendation for Approval for Operation of the New RHIC LN2 Tanks at Building 1005H*

The Cryogenic Safety Subcommittee of the BNL ES&H Committee has reviewed the installation of two new RHIC liquid nitrogen tanks located at Building 1005H in our meeting of October 1, 2003. The tanks replace an existing low pressure LN2 tank and associated nitrogen compressor.

Our review focused on the cryogenic safety aspects of the installation. The C-AD Accelerator Systems Safety Review Committee (ASSRC) conducted the conventional safety review. ASSRC will require LESHC Chairperson approval as part of the new LN2 tanks commissioning process.

The Minutes of LESHC Meeting 03-08 are attached to this memo for your information. The Minutes contain a Committee Motion that documents several conditions that must be completed prior to system commissioning. As of the date of this memo, all conditions have been completed by the Collider-Accelerator Department.

Therefore, the Committee recommends granting approval for operations of the new RHIC LN2 tanks at Building 1005H after the pre-operational conditions identified by the ASSRC are satisfied.

CC w/ attachment (via Email):

LESHC Members
Meeting Attendees
M. Beckman
P. Kelley (BAO)
T. Kirk
D. Lowenstein
L. Marascia
T. Monahan
D. Ryan
R. Travis
J. Tuozzolo

SAFETY REVIEW OF REPLACEMENT OF 1005H N2 DEWAR WITH TWO PRESSURIZED DEWARS

Use Nitrogen directly from pressurized Dewars to supply pneumatics for refrigerator, compressor room, warm gas storage tanks, liquid storage area near 1006B, liquid Nitrogen Dewar at 1006B and 80K cooler.

Eliminates water in pneumatic system.

Eliminate Nitrogen Compressor (formerly used for Pneumatics)

Dewars formerly ran at reactor up until its shutdown.

Expected Operating Pressure of Dewars: 100 Psig. MAWP of Dewar – 250 psig

These dewars will also supply

- Liquid Nitrogen for the Purifier in 1005H
- Liquid Nitrogen for the cold trap on the Oil Processing Skid
- Gas purge for the purifier cold box.
- Nitrogen for the purifier warm-up

Replaces Current System

- 20000 gallon dewar operated at 40 psig – supplied N2 to compressor which was used for pneumatics.

OPERATIONAL FEATURES

-Each Dewar can hold approximately 6000 gallons of Liquid N2 for a total of 12000 gallons

-Historical N2 usage at 1005H is: 2000 gallons/day so there is a 6 day store if the dewars are full

-Each dewar has a maximum withdrawal rate of 5000 gallons/day while maintaining 100 psi. (From Taylor Wharton, Dewar manufacturer)

-Connections incorporated to ring air system at 1006B and 1005R – if air pressure goes too low crossover valves OPEN. This will be automated in the Cryogenic Control System.

-Ability to operate off of one dewar while the other is warm and or being repaired.

- Original N2 compressor uses as backup should Dewars not be able to sustain pressure.

- Constant monitoring of Dewar operational parameters in Cryogenic Control Room.
  - -Dewar Pressure
  - - Liquid Level
  - Alarms on dewar overpressure.

SAFETY FEATURES

Tanks built to ASME BPV code Section VIII Division I
Certified 1987 psig. MAWP 250 psig.

Transfer Lines built to ASME B31.3

All trapped volumes protected by relief valves.

Entire system will be pressure checked, including all new welds

All relief valves sized and set for new operating pressure.
Relief Valves on Transfer Lines set to 140 Psi
Relief Valves on tanks set to 150 psi

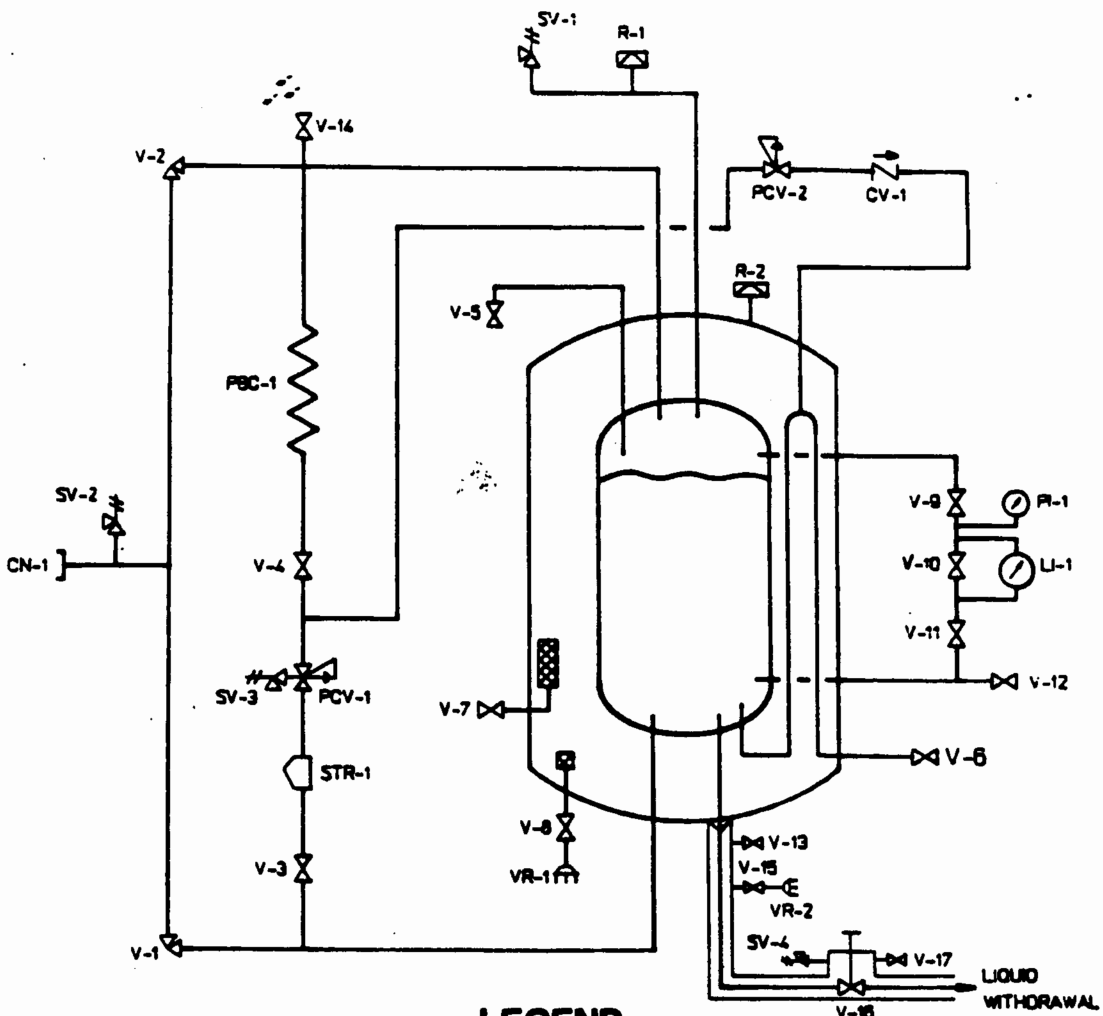
DESCRIPTION

This manual provides operating and maintenance instructions for a TM-6000 NICS. It is designed for the storage of liquid oxygen, nitrogen or argon at a maximum allowable working pressure of 250 psig. For general specifications, design and construction information, see Table 1 and Taylor-Wharton Drawing C-2200090.

Table 1 - Tank Specifications

TANK PART NUMBER	2200081
DIMENSIONS & CONNECTION PART NUMBER	2200090
SERVICE	O_2,N_2,Ar
GROSS CAPACITY (Gal.)	6,020
(lit.)	22,788
NET CAPACITY (Gal.)	5,880
(lit.)	22,258
MAXIMUM WORKING PRESSURE (PSIG)	250
(kPa)	1,724
TANK WEIGHT	
Empty (Lb.)	28,200
(Kg.)	12,792
FULL - LIQUID OXYGEN (Lb.)	84,220
(Kg.)	38,202
LIQUID NITROGEN (Lb.)	67,900
(Kg.)	30,799
LIQUID ARGON (Lb.)	96,570
(Kg.)	43,804
MATERIALS OF CONSTRUCTION	
Insulation	Perlite per MPS-1000
Vacuum Jacket	ASME SA-283, Grade "C", or ASTM A-36 Steel
Pressure Vessel	ASME SA-353/553-9% Nickel Steel
Internal Piping	ASTM A-312, Type 304 Stainless Steel
DIMENSIONS	
Height (Maximum)(ft)	26'-2.75"
(m)	8.0
Diameter (Maximum)(ft)	8'-0"
(m)	2.44

FLOW DIAGRAM



LEGEND

V-1	BOTTOM FILL VALVE
V-2	TOP FILL VALVE
V-3	PRESSURE BUILDING INLET VALVE
V-4	PRESSURE BUILDING ISOLATION VALVE
V-5	FULL TRYCOCK VALVE
V-6	PRODUCT WITHDRAWAL VALVE
V-7	EVACUATION CONNECTION VALVE
V-8	VACUUM GAUGE TUBE VALVE
V-9	VAPOR PHASE ISOLATION VALVE
V-10	EQUALIZATION VALVE
V-11	LIQUID PHASE ISOLATION VALVE
V-12	AUXILIARY BLEED VALVE
V-13	EVACUATION CONNECTION VALVE
V-14	VAPOR VENT VALVE
V-15	VACUUM GAUGE TUBE VALVE
V-16	"VJ" LIQUID WITHDRAWAL VALVE CONN.
V-17	CPC SPECIAL EVACUATION VALVE
SV-1	SAFETY VALVE
SV-2	RELIEF VALVE
SV-3	RELIEF VALVE
SV-4	RELIEF VALVE
CV-1	ECONOMIZER CHECK VALVE
PCV-1	PRESSURE BUILDING CONTROL VALVE
PCV-2	ECONOMIZER PRESSURE REGULATOR
R-1	RUPTURE DISC
R-2	RUPTURE DISC. CASING
VR-1	THERMOCOUPLE GAUGE TUBE
VR-2	THERMOCOUPLE GAUGE TUBE
CN-1	FILL CONNECTION
STR-1	STRAINER
PI-1	PRESSURE GAUGE
LI-1	LIQUID LEVEL GAUGE
PBC-1	PRESSURE BUILDING COIL

FIGURE 2. FLOW DIAGRAM

FUNCTIONAL DESCRIPTION

The TM-6000 NICS is of double-walled construction and consists of a pressure vessel, a high performance insulation system and a vacuum jacket.

The pressure vessel is designed and manufactured in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. It is constructed of ASME SA-353/553, 9% Nickel Steel.

The outer vessel is constructed of ASME SA-283, Grade "C"or ASTM A-36, Steel.

Vacuum System

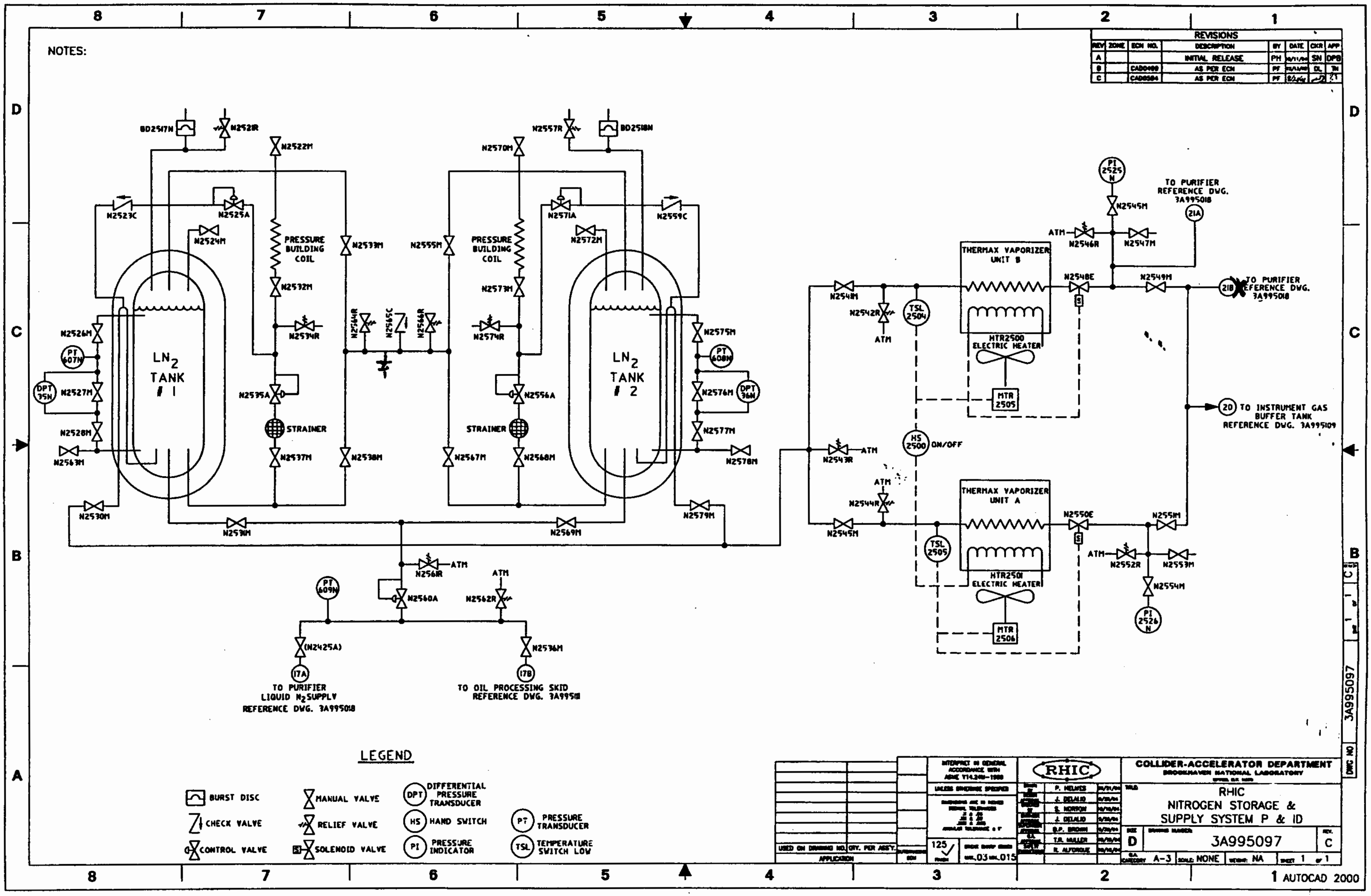
The TM-6000 is vacuum insulated. The space between the pressure vessel and vacuum jacket is filled with perlite insulation, pumped to a high vacuum and factory sealed. Although the evacuation valve is sealed at the factory, it may be used for field re-evacuation if necessary. An adsorbent is installed in the vacuum space to help maintain the vacuum by adsorbing any outgassing from the materials in the vacuum space.

The tank vacuum can be checked in the field by using the thermocouple-type vacuum gauge tube located on the bottom head of the tank.

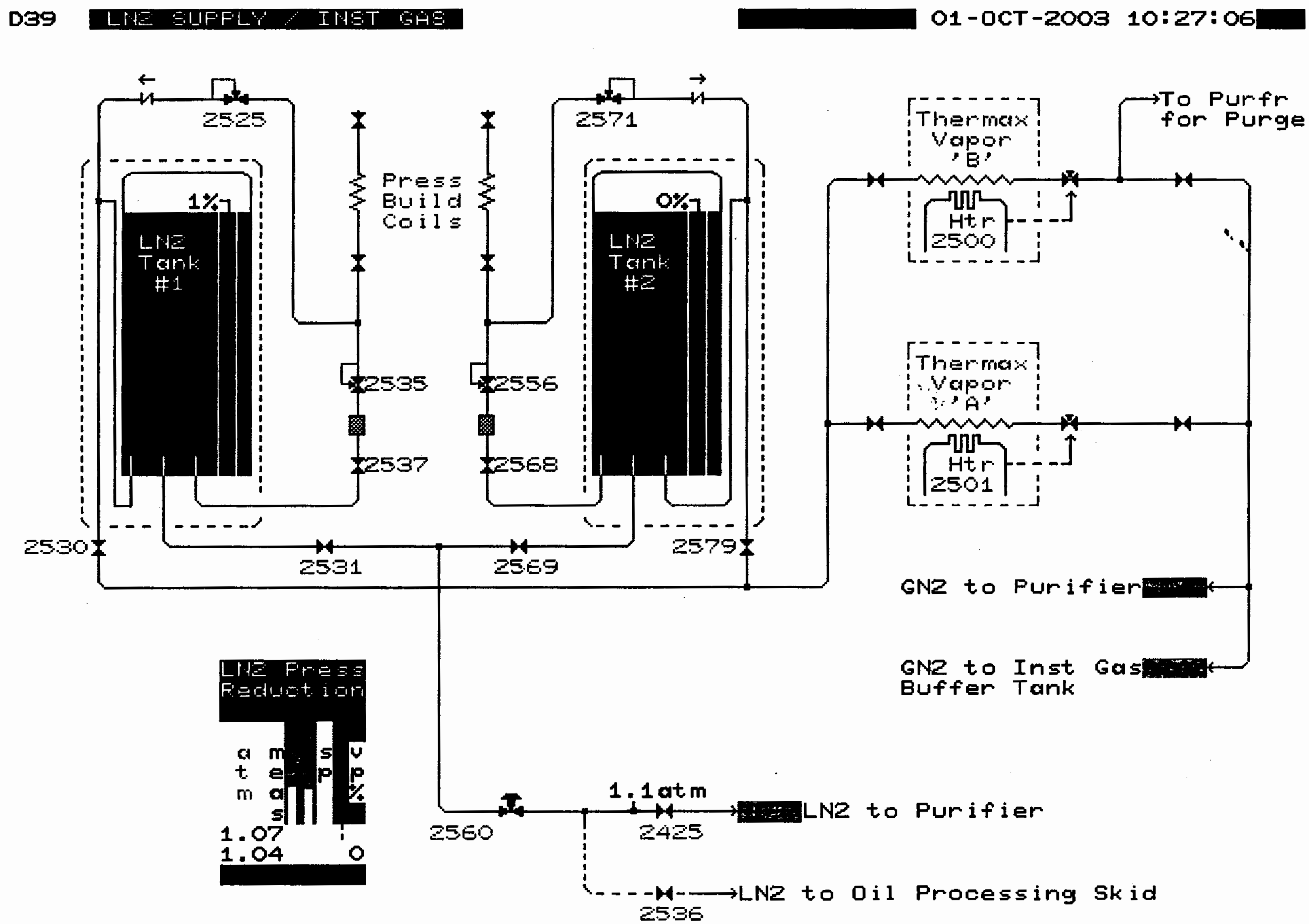
Fill/Withdrawal

The tank is filled with product through the fill connection and two right-angle extended stem valves. The bottom fill valve is connected to the bottom of the pressure vessel and the top fill valve is connected to the top of the pressure vessel. Filling gas phase tends to decrease the tank pressure; while filling liquid phase tends to increase tank pressure. The vapor vent valve is opened for venting and throttled to maintain tank pressure during liquid phase filling. The full trycock valve is used to determine when the tank is full. An auxiliary bleed valve is provided to confirm the tank is empty for maintenance purposes.

Product is normally withdrawn as liquid through a liquid withdrawal line originating at the bottom of the pressure vessel. Liquid flows through the withdrawal valve to a vaporizer. When the pressure building coil valve is open and tank pressure exceeds the setting of the economizer valve, gas will flow from the top of the tank through the pressure building coil and the economizer valve to the high point liquid withdrawal line. This action interrupts the flow of liquid, allowing gas to flow through the withdrawal line until tank pressure falls below the setting of the economizer valve, causing it to close. This economizer action reduces product losses by allowing the withdrawal of gas that would otherwise be vented through the main safety relief valve. This tank is also equipped with a vacuum jacketed liquid withdrawal line.



NOTES:
REVISIONS
REV | ZONE | ECN NO. | DESCRIPTION | BY | DATE | CKR | APP
A | INITIAL RELEASE | PH | SN | DPB
B | CAD0490 | AS PER ECN | PF | DL | TH
C | CAD0584 | AS PER ECN | PF
LN2 TANK # 1
LN2 TANK # 2
PRESSURE BUILDING COIL
STRAINER
THERMAX VAPORIZER UNIT B
THERMAX VAPORIZER UNIT A
HTR2500 ELECTRIC HEATER
HTR2501 ELECTRIC HEATER
MTR 2505
MTR 2506
HS 2500 ON/OFF
TSL 2504
TSL 2505
PT 607N
PT 608N
PT 609N
DPT 35N
DPT 36N
PI 2525 N
PI 2526 N
BD2517N
BD2518N
N2521R
N2522M
N2523C
N2524M
N2525A
N2526M
N2527M
N2528M
N2530M
N2531M
N2532M
N2533M
N2534R
N2535A
N2537M
N2538M
N2541M
N2542R
N2543R
N2544R
N2545M
N2545M
N2546R
N2547M
N2548E
N2549M
N2550E
N2551M
N2552R
N2553M
N2554M
N2555M
N2556A
N2557R
N2559C
N2560A
N2561R
N2562R
N2563M
N2564R
N2565C
N2566R
N2567M
N2568M
N2569M
N2570M
N2571A
N2572M
N2573M
N2574R
N2575M
N2576M
N2577M
N2578M
N2579M
(N2425A)
N2536M
ATM
TO PURIFIER REFERENCE DWG. 3A995018
TO PURIFIER REFERENCE DWG. 3A995018
TO INSTRUMENT GAS BUFFER TANK REFERENCE DWG. 3A995109
TO PURIFIER LIQUID N2 SUPPLY REFERENCE DWG. 3A995018
TO OIL PROCESSING SKID REFERENCE DWG. 3A995111
LEGEND
BURST DISC
CHECK VALVE
CONTROL VALVE
MANUAL VALVE
RELIEF VALVE
SOLENOID VALVE
DIFFERENTIAL PRESSURE TRANSDUCER
HAND SWITCH
PRESSURE INDICATOR
PRESSURE TRANSDUCER
TEMPERATURE SWITCH LOW
RHIC
COLLIDER-ACCELERATOR DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
RHIC
NITROGEN STORAGE &
SUPPLY SYSTEM P & ID
P. HELAKS
J. DELAUO
S. NORTON
J. DELAUO
B.P. BROWN
T.R. MULLER
R. ALFORQUE
D
3A995097
C
A-3
SCALE NONE
WEIGHT NA
SHEET 1 of 1
125
DWG NO 3A995097
USED ON DRAWING NO.
QTY. PER ASSY.
APPLICATION
AUTOCAD 2000



Screen 39, from CRT4, 01-OCT-03 10:26:54 LN2 Supply / Instrument Gas

COMPONENT PRESSURE RATINGS

Thermax Heater: 440 psig

Transfer Lines: 150 psig

Nitrogen tanks: 250 psig

Copper Tubing:

2 inch, Hard Drawn, Soldered type L: 625 psig

Connections to Nitrogen System (ref 3A995097)

21A:Nitrogen purge. To section of purifier designed for instrument air

21B: Formerly to low-pressure area of purifier cold box. Connection will be removed

20: To pneumatic system. Components in pneumatic system designed for 150 psi.

17A: Liquid N2 Fill for purifier and cold trap on oil processing skid. Valve N2560A is designed to maintain pressure at the inlet of the purifier and oil processing skid at 40 psig, as it has run in the past. Valve is fail closed

FAILURE MODES

Loss of Power

- Dewar will remain pressurized
- Supply valve to Purifier and Oil Processing skid will close.
- Thermax heaters will shut off and valves will close.
- No safety Issues

Loss of insulating vacuum on Dewar or transfer line

- Tanks of Protected by ½ inch Anderson Greenwood Relief valves
- Transfer lines would pressurize until relief setting of 140 psi is reached
- Supply valve, N2560A would close as it is trying to maintain a constant downstream pressure so the purifier would not pressurize.

Failure of valve in pressurizing coil:

- Dewar over pressurizes – protected by relief valves.

Liquid Supply Valve, N2560 Fails Open

- Purifier
    - Valve downstream of N2560 is a pressure-regulating valve as well. Should maintain pressure in purifier
    - Otherwise, purifier protected by relief valves and N2 vent to atmosphere.
- Oil Processing skid
    - Protected by relief valves and N2 vent to atmosphere.

ODH

- Compressor is ODH 0 during Operations
- Calculations indicate because of higher working pressure, there will be an increase in the flow of N2 into the building in the event of a pipe rupture.
- Original estimate – 1500 SCFM
  New Estimate –2000 SCFM
  Need to recalculate ODH for building.

PROCEDURES/TRAINING

- Fill Procedure.
  Modify of existing tank fill procedure to reflect two tanks installation
- Cryo Operator training class on new pneumatic system.

EQUIPMENT FAILURE AND HUMAN ERROR RATES

Additional Risk Assessment Data

Table B-I gives estimates of cryogenic equipment failure rates. These data are median estimates collected from past ODH risk assessments performed on systems at Fermilab. This data has been updated to include the revised failure rate estimates as described by B. Soyars (Fermilab) report, " Appendix: Rationale for Table 1 - Fermilab Equipment Failure Rate Estimates," dated January 26, 2000. Table B-II shows failure rates for various equipment types derived from the nuclear power industry that may be useful as input data (MOV - Manually operated valves/SOV - Solenoid operated valves/AOV - Automatically operated valves). General human error rate estimates are presented in Table B-III. Table B-IV lists conservative estimates of the rate of human error as a function of task type and time limit.

TABLE B-I
FERMILAB EQUIPMENT FAILURE RATE ESTIMATES

Component	Failure Mode	Estimated Median Failure Rate
Compressor (Cryogenic)	Leak Rupture	5×10^{-6}/HR 3×10^{-7}/HR
Dewar	Leak or Rupture	1×10^{-6}/HR
Electrical Power Failure (unplanned)	Time Rate Demand Rate Time Off	1×10^{-4}/HR 3×10^{-4}/Demand 1 HR
Fluid Line (Cryogenic)	Leak Rupture	5×10^{-7}/HR 2×10^{-8}/HR
Magnet (Cryogenic, Powered, unmanned)	Leak or Rupture	2×10^{-7}/HR
Magnet (Cryogenic, Not Powered, unmanned)	Leak or Rupture	2×10^{-8}/HR
Header Piping Assembly	Rupture	1×10^{-8}/HR
Change of Equipment with Bayonet Fitting (Cryogenic Release)	Small Event Large Event	3×10^{-2}/Demand 1×10^{-3}/Demand

TABLE 4-A-2

Oxygen Deficiency Hazard Classification of RHIC Buildings During Normal Operations

Bldg. No.	Building Name	Bldg. Vol. Cu. Ft	Fan CFM	Occup. ManD/D	Peak He SCFM#	Peak N_2 SCFM#	ODH Class*
1005H	Compressor Bldg.	250,000	100,000	0.1	8,000	1,500	0
1005S	Refrigerator Bldg.	240,000	50,000	0.3	27,000	0	1
1005E	Power Supply/Croyogenic Bldg.	TBD	TBD	TBD	TBD	TBD	TBD
1001	Collider Tunnel - 1:00	310,000	60,000	0	150,000	0	0
1003	Collider Tunnel - 3:00	300,000	60,000	0	150,000	0	0
1005	Collider Tunnel - 5:00	390,000	60,000	0	150,000	0	0
1007	Collider Tunnel - 7:00	400,000	60,000	0	150,000	0	0
1009	Collider Tunnel - 9:00	320,000	60,000	0	150,000	0	0
1011	Collider Tunnel - 11:00	300,000	60,000	0	150,000	0	0
1002B	2:00 Support Bldg.	70,000	32,000	0.1	17,000	0	0
1004B	4:00 Support Bldg.	113,000	44,000	0.1	17,000	0	0
1006B	6:00 Support Bldg.	85,000	32,000	0.1	17,000	1,500	0
1008B	8:00 Support Bldg.	75,000	32,000	0.1	17,000	0	0
1010A	10:00 Service Bldg.	110,000	22,000	0.1	17,000	0	0
1012A	12:00 Service Bldg.	110,000	22,000	0.1	17,000	0	0

*Classes per RHIC Project Safety OPM 5.2.2.4.1, "Oxygen Deficiency Hazards (ODH)."
#ODH calculations were based on the integrated time dependent release.

Prepared by: R. Karol Date: 10-02-03

Approved by: D. Lowenstein Date: 10/3/03

ASSRC Check-Off List for **1005H LN2 Tanks Walkthrough**

Date of Meeting **10-02-03**

Comments: Minutes of ***Walkthrough of Building 1005H New LN2 Tanks on October 2, 2003***

To be completed prior filling LN2 Tanks.

Checklist Item # (e.g., CK-01)	Initials	Title	Description of Check-Off List Item
CK-01	RCL	LESHC	LESH Chair concurs with isolating and filling of the two LN2 tanks
CK-02	TN	CGL	The fill line at the east side of the tanks needs protection in place before filling the tanks to prevent vehicles and LN2 delivery trucks from impacting the piping
To be completed while filling LN2 Tanks.			
CK-03	[illegible]	IH	Perform noise survey during filling the LN2 Tanks, post area appropriately.

To be completed prior to use of LN2 System beyond Tanks outlet valves.

CK-04	EL	LESHC	All issues and concerns of the LESHC Cryogenic Sub-Committee are addressed
CK-05	PK	EE	The two thermax vaporizer units need to be verified to be properly grounded before energizing

LESHC – Lessard CGL – T. Nicoletti or A. Warkentien

IH – P. Cirnigliaro or F. Horn

EE – P. K. Feng

I allow routine operations to commence.

Signature Accelerator Division Head,

Copy List to ASSRC Files

Tony Nicoletti
10/10/2003

Relief Valve on Thermax Heater
Calculations Concerning Cryogenic Safety Review of LN2 TANKS AT 1005H

Calculations Based on Equation on Attached Sheet

Case 1
Thermal relief valve sized to take static heat load of piping
with inlet and outlet valves closed with liquid in Line
Assumption:uninsulated line
GAS at outlet of relief Valve

From Original Relief Valve Data

Size:	36	scfm	air flow rate
Ma	29		molecular weight of air
Ta	492	K	relief temperature
Z	1		compressibility factor
C	356		constant
K	0.9		Nozzle coefficient
P1	165	psi	
Area	0.015	in^2	relief valve orifice area

Convert to Nitrogen at expected operating conditions

MN2	28		molecular weight of n2	
Tn2	234	R	relief temperature	130 K
Z	1		compressibility factor	
C	356		constant	
K	0.9		Nozzle coefficient	
P1	165		psi	

SCFMN2	53.1	scfm N2
STP density of N2	0.001251	g/cc
	35.424	g/ft^3
	1881.9	g/min
	31.4	**g/sec** — **Relief valve Capacity**

Compare to Heat Flux from Free Convection on Outside of Pipe

Convective heat transfer Calculation:

Pipe temperature:	130	K	worst case
Ambient temp:	300	K	
Tfilm=	215	K	

Air

k=	0.0196	W/m-K	
Beta	0.0047	K-1	
visc	0.0001	lbm/ft-sec	0.0013904 g/m-sec

Cp	1.0420 j/g-k	Specific Heat	
k=	0.0196 w/m-k	Thermal Conductivity	
Pr	0.0739	Prandtl Number	
d	0.0060 m		
Density:	0.0993 lb/ft^3	0.0015943 g/cc	1594 g/m^3
visc	8.72E-07		
GrD/Pr	165329		

Constants from Table 7-1 in Holman:

C	0.53	Constant
m	0.25	constant
Nu=	10.69	Nusselt Number

h=	35 W/m^2K	Convective Heat Transfer Coefficient
Q=	112 Watts/meter	Heat Flux

Assume 10 meters of pipe at 130K

Q in 1118 Watts

140 j/g Heat of vaporization of N2: at 140 psi

Flow capacity Required: 8.0 g/sec

Relief valve capacity: 31 g/sec

CONCLUSION: RELIEF VALVE HAS ENOUGH CAPACITY

Case 2
Thermax heater Remains on With Inlet and Outlet Valves Closed

Assumptions:
Relief valves are on inlet to Thermax, so assume they will flow Liquid N2

From Relief Valve Sizing Formula

A	0.15 in^2	relief valve orifice
G	0.8	specific gravity of LN2
K	0.81	nozzle coefficient
Kp	1	Overpressure correction
Kw	0.8	Back pressure correction factor
Kv	0.7	viscosity correction factor
Vl=	35 GPM	Liquid Flow Rate Through Relief Valve
	6.672 lbs/gallon	
	236.2 lb/min	
	3.9 lb/sec	
	1.8 kg/sec	
	1789.5 g/sec	

Enthalpy of Nitrogen at Release Point 96.12 j/g

Thermax Heater Capacity 35 kW
Add static heat load: 1.12 kW

Total Load: 36.1 kW
Energy Released through Relief Valve: 172.0 kW
CONCLUSION:RELIEF VALVE HAS ENOUGH CAPACITY

Pressure Drop In Line to Thermax Relief Valve
Inlet and Outlet Valves Closed, heater powered

3/8 Tube

OD	0.375 in	0.95 cm
Wall	0.032 in	0.08 cm
ID	0.311 in	0.79 cm
Area	0.076 in^2	0.49 cm^2

Stp density of Ln2 0.001 g/cc
0.020 g/in^3
35.396 g/scf

Density of Liquid Nitrogen 0.808 g/cc
viscosity of ln2 0.00292 g/cm-sec

Reynolds number

Flow g/sec	re	flow scfm	f	dp N/m^2	L cm	dp psi
1600	880941	2712.2	0.027	1351631	6	248

Resultant Pressure in Thermax heater: 408.0 psi
Thermax Pressure rating: 440 psig
Thermax Max test pressure: 575 psig
CONCLUSION: PRESSURE IN THERMAX BELOW DESIGN PRESSURE

Sizing – English Sizing Formulas

Vapors or Gases (capacity in SCFM)[1]

$$A = \frac{V\sqrt{MTZ}}{6.32\ CKP_1}$$

Vapors or Gases (capacity in lb/hr)[1]

$$A = \frac{W\sqrt{TZ}}{CKP_1\sqrt{M}}$$

Steam (capacity in lb/hr)[1]

$$A = \frac{W}{51.5\ K\ P_1\ K_s}$$

Liquids (capacity in gpm)

$$A = \frac{V_L\sqrt{G}}{38\ K\ K_P\ K_W\ K_V\sqrt{P_A - P_B}}$$

English Sizing Formulas

Orifice area calculations are made and/or verified whenever sufficient data is provided. If no data is furnished, the size selection responsibility will remain totally with the purchaser.

V = Required capacity, SCFM

W = Required capacity, lb/hr

V_L = Required capacity, gpm

G = Specific gravity of liquid at flowing temperature referred to water = 1.00 at 70°F (see Physical Properties on pages 12 - 14)

M = Molecular weight of vapor or gas ($M = 29 \times G$, see Physical Properties on pages 10 - 11)

T = Relief temperature, °R (°R = °F + 460)

Z = Compressibility factor (if unknown, assume $Z = 1.0$)

k = Specific heat ratio $k = \frac{C_p}{C_v}$

C = Gas constant based on k (if unknown, assume $C = 315$; see Physical Properties on pages 10 - 11; also see page 8)

K = Nozzle coefficient for 90 percent of actual capacity, derived from National Board Certified Testing (see page 4)

P_1 = Inlet flowing pressure, psia = Set pressure - inlet pressure loss + allowable overpressure + 14.7

P_A = Inlet flowing pressure, psig = Set pressure - inlet pressure loss + allowable overpressure

P_B = Back pressure - psig

K_p = Overpressure correction factor, 1.0

K_w = Back pressure correction factor (see page 7)

K_v = Viscosity correction factor (see page 7)

K_s = Superheat correction factor (for saturated steam, $K_s = 1.0$, refer to Table on page 9)

1. As is accepted industry practice, built-up back pressure for conventional (unbalanced) gas or steam valves should not exceed 10 percent.